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Wearing Comfort of Footwear in Hot Environments

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Dedicated to Dir. and Prof. Kunz on his 60th birthday

INTRODUCTION

The climatic wearing comfort of military footwear greatly influences the performance of the soldier. Particularly in hot and/or humid environments insufficient wearing comfort of footwear can cause severe problems. Considering that the formation of blisters can be considerably reduced if the feet are kept as dry as possible [1], means should be provided to reduce the humidity close to the surface of the foot. Even though a great diversity of so called "functional" socks and "breathable" shoes are available on the market today, there is still a lack of reliable and objective methods to simulate sweating inside the footwear at different levels of metabolic rate and to measure the resultant temperatures and relative humidities. It is, therefore, difficult to judge or compare different footwear systems (consisting of shoes, socks and inlay soles) with respect to their influence on the climatic wearing comfort.

RATIONALE

In collaboration between WIWEB and IfaErg a testing device named CYBOR (Cybernetic Body Regulation) for the simulation of climatical conditions inside a footwear system and the measurement of the resulting temperatures and relative humidities close to the foot and/or between sock and shoe has been developed. The technical specifications together with some samples of application of the device have been reported earlier [2-4]. CYBOR consists, among other, of a foot phantom, which supplies heat and moisture to the inside of footwear. The heat and moisture supply is closely related to human sweating behaviour at a given metabolic rate. An investigation has been carried out to find out about a suitable combination of socks and shoes resulting in a proposition for footwear systems to be worn in hot and hot/wet environments.

RESULTS

Five different pairs of socks with two-layer construction underneath the foot and a mixture of man made and natural fibres within the shaft have been combined with a german combat boot particularly designed for hot environments. The details of the construction of the socks are given in Tab. 1.

The temperature and relative humidity inside the foot phantom of the simulation device were set to 37 °C and 80 % relative humidity, respectively. After reaching a steady state condition (after approx. 90 min. of test duration), the temperature and relative humidity were measured in the medial area outside the foot phantom ("skin" in Fig. 1) as well as in the medial area between the sock and the shoe. Fig. 1 shows the resulting calculated water vapour pressure (wvp) values.

Tab. 1: Construction details of socks under test and final temperatures at the end of the test as measured in the medial area.; WO = Wool, PAC = Polyacryl, PA = Polyamide, PES = Polyester (Coolmax[®]), PP = Polypropylene.

Sock No.	Cushion (PP)	Thickness of Shaft	Length	Fibremixture	Final temperature
1	High Volume	low	calf	WO/PAC	34,2
2	Medium Volume	low	calf	WO/PAC/PA	34,6
3	Medium Volume	low	calf	PES/PA	34,4
4	High Volume	high	calf	WO/PAC/PA	34,7
5	High Volume	high	knee	WO/PAC/PA	34,5

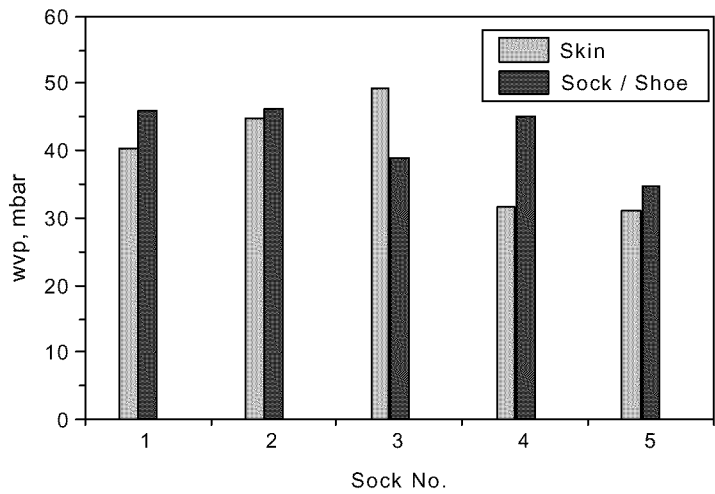


Fig. 1: Water vapour pressure (wvp) measured in the medial area inside (“skin”) and outside (“sock / shoe”) the socks under test.

Socks with thinner shafts (No. 1 - 3) tend to produce a more humid climate close to the skin even with a high volume cushion underneath the foot. The driest climate is provided by socks No. 4 and 5 with thick shaft and a high volume cushion. Sock No. 4, however, shows a comparatively high wvp-value between the sock and the shoe. The final temperatures inside all the socks under test are within a range of 0.5 °C, which means that the difference cannot be realized by the wearer. The results are interpreted as follows:

There are three different ways of moisture transport out of the shoe (Fig. 2):

1. from the skin through the sock through the material of the shaft of the shoe
2. from the skin through the sock along the inside of the shaft of the shoe
3. along the inside of the sock

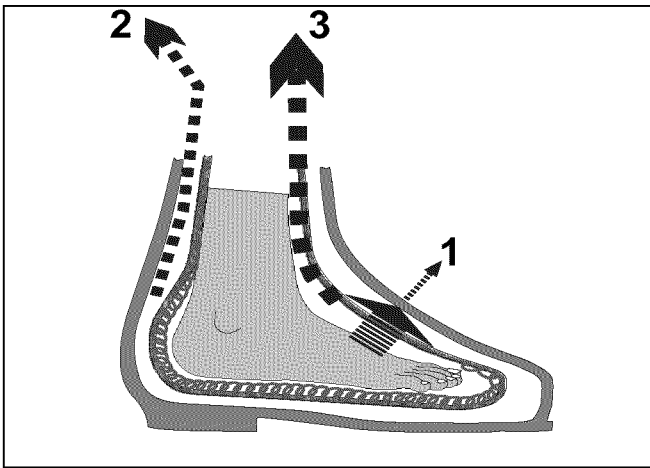


Fig. 2: Different options for moisture exchange in footwear (explanation of numbers: see text)

Option No. 1 is limited by the water vapour permeation resistance of the shoe's shaft material. Even though the shoe under test was equipped with fabric insets, the results show, that in most cases the water vapour pressure between the sock and the shoe is higher than close to the skin, which means, that the moisture transport through the shaft of the shoe is insufficient. The same applies to option 2. In case of a good fit of the shoe this transport way is blocked by a snug contact between the sock and the shoe. The most efficient way of removing moisture from the feet seems to be option 3. This can be seen from the comparatively lower "inside" wvp-values of socks 4 and 5 with thick shafts.

Two further important informations can be drawn from the results: In case of sock No. 3 the content of a high surface fibre (Coolmax®) within the shaft evidently provides a better moisture transport and a drier climate between the sock and the shoe compared to socks No. 1 and 2. No. 3, however, was the thinnest sock under test and some of the moisture loss may also be due to the loose fit between sock and shoe. The content of this particular high surface fibre in the shaft material of the sock does, however, not provide a drier climate close to the skin. In case of sock No. 4 the moisture transport option 3 may be blocked by the elastic upper end of the shaft of the sock close to the upper end of the shoe. In contrast to the knee-high sock No. 5 most of the moisture is left between the sock and the shoe, which can cause problems during longer wearing periods.

CONCLUSION

The obtained results showed, that the construction of socks have a major influence on the climatic wearing comfort of footwear systems for extreme environments. It turned out, that comparatively thicker socks will provide a drier foot climate without considerably raising the skin temperature.

Currently further tests are carried out to get more precise informations about the influence of different man made fibres with good moisture transport capabilities on the foot climate. The employed testing device CYBOR has proved to be a powerful tool for the prediction of the climatic wearing comfort of footwear systems.

The authors thank the Falke KG Company, Germany for supplying the necessary test samples.

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